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Effect of reafforestation by conifers in natural biotopes of middle and South Navarra (Northern Spain)[1]

par

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Avec 6 figures

ABSTRACT

The effects on soil fauna (Nematoda, Oribatei and Collembola) of reafforestation with *Pinus nigra* and *Pinus halepensis,* in two sites of Middle and South of Navarra have been studied. The analysis of Equitability, Richness and Similarity, as well as comparisons among biotopes by means of correspondences analysis, have been made.

INTRODUCTION

This work is a part of the CAICYT research contract No. 0220, entitled "Effect of the Forestal Exploitation and Reafforestation on the Soil Fauna". The aim of this study is to determine the relationships between the actual fauna of the soil of a natural environment and the fluctuations induced by both seasonal changes and the reafforestation with pine species.

The soil fauna and their dynamics may be useful as monitors of the productivity and stability of soils. Several authors (CASSAGNAU 1961; BONNET *et al.* 1976; PONGE 1983; GERS & IZARRA 1983; ARPIN *et al.* 1984) have pointed out the quality of the soil fauna as biological indicators.

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In a former paper (ARBEA & JORDANA 1985) the effect of a coniferous reafforestation and fell on a beech forest in Quinto Real (Humid Navarre) was studied. It was determined that the reafforestation with larch produced a rupture in the Collembola population dynamics. This fact was also observed by BONNET *et al.* (1976, 1979).

METHODOLOGY

Samplings. As this work is a part of a wider one, which comprised the study of the woods of Navarra with more than 500 samplings in one single year, the sampling was performed once in each season in each site. Every sample was 25 × 25 cm, being of different depth depending upon the amount of litter. The *A1* horizon was sampled up to about three cm deep, since this research concerns to the fauna involved in the natural transformation of the organic materials. The samples were extracted level by level, although here we present the global results. The weight of each sample was between 800 and 1000 g. For the study of the Nematoda, 20 g of each horizon were taken from the original sample, after homogenization.

The data presented here are referred to 100 g dry weight of soil. Species ocurring in less than one percent of the total have been omitted. The total number of determined specimens of acari, collembola and nematoda is 68,436.

Extractions. In order to obtain the complete nematocenoses, the Nematoda were extracted by means of the centrifugation method in sucrose of CAVENESS & JENSEN 1955, redescribed by GRISSE 1969, and modified by NOMBELA & BELLO 1983, and by MONTENEGRO 1986. Staining was performed with Fuchsine and mounting was in Lactophenol (FRANKLIN'S & GOODEY'S method, 1949) and in Glycerine (SEINHORST'S method, 1959).

The mesofauna of microarthropods was extracted by the method of TULLGREN, 1918, modified as follows: The funnels were made of inox steel, 20 cm diameter and 25 cm deep, with an opening of two cm at the base. The sample containers were 15 cm diameter and 8 cm deep, with 2 mm mesh sieves fitted at the bottom. The lighting was from 15 watt electric bulbs, placed 12 cm above the surface of the sample. The temperature at the surface of the sample was 22° C. The animals were collected into 70 percent aqueous ethyl alcohol with five percent glycerol during the six-day extraction period. EDWARDS & FLETCHER have compared several extraction methods for edaphic invertebrates of forest soils. For the microarthropods, they have compared, among others, the *Rothamsted controlled-gradient funnels (with heat)* and the *MacFayden high gradient canister extractor.* The former one shows better efficiency than the latter, and is by far the one must used by the soil ecologists. Our method is similar to this one. Judging by the number of larval stages of microarthropods, specially of acari Prostigmata and Mesostigmata which are currently under study in the Acarology Laboratory of The Columbus University, Ohio (USA), the method proves to be very efficient (JOHNSTON, personal communication).

STATISTICS

The following statistics were calculated: The Richness (R) index of MARGALEF 1951; the J index of Equitability (LLOYD & GHELARDI 1964); the T coefficient of similarity (LOOMAN & CAMPBELL 1960). Also, some Correspondences Analysis were performed using the ANAFACOR program (LAGARDE 1983) modified by ARBEA and ARIÑO.

SAMPLING SITES

1. BARDENAS. In the arid area of Bardenas (South of Navarre) two sites were chosen: one was a mediterranean bush biotope with an arid vegetation belonging to *Rosmarino-Ericion* aliance and *Rosmarino-Linetum subfruticossi* association, supporting an endemic *Gipsophilion* alliance on the gypsum outcropping (URSUA *et al.* 1984). The other was located fifty meters away, being a *Pinus halepensis* evergreen forest planted thirty years ago.

2. SANSOAIN. The natural biotope chosen was a *Quercus rotundifolia* oak evergreen forest of the *Quercetea-ilicis* class, *Quercion-ilicis* alliance, located on a North-facing slope. This is the potential vegetation of the area. In the same slope, a substitution biotope of reafforested *Pinus nigra* was selected.

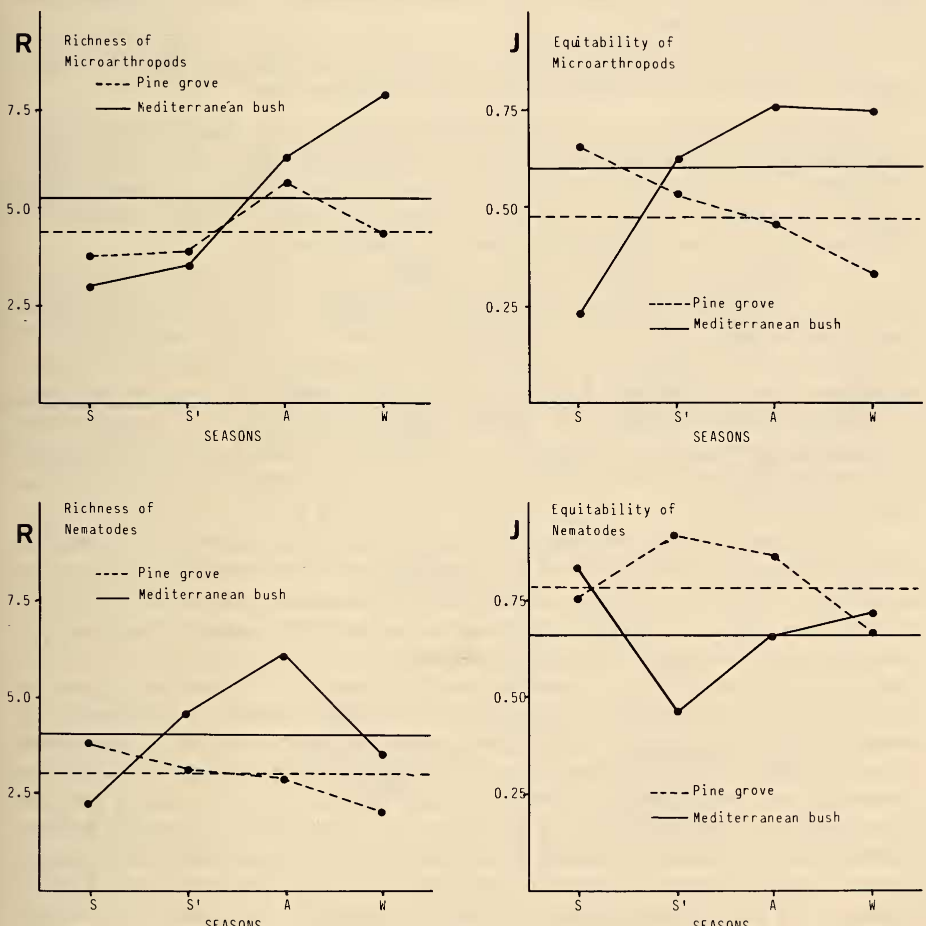

FIG. 1.

Seasonal variation of Richness (R) and Equitability (J) in Bardenas S: Spring; S': Summer; A: Autumn; W: Winter. Horizontal lines: Average of each one.

RESULTS

BARDENAS (Bush and Pine forest).

In the bush soils a total of 102 species (seventy-one of Oribatei and thirty-one of Collembola) have been found. Out of them, thirty-four Oribatei and twenty-two Collembola are exclusive of this environment, having disappeared in the pine forest.

The soil of the pine grove shows an original microarthropod population with thirty-nine exclusive species (thirty-one Oribatei and eight Collembola) of the total eighty-five species (sixty-eight Oribatei and seventeen Collembola).

When calculating the Equitability and Richness indices (fig. 1) it can be observed that the Richness is lower in spring and summer in both biotopes, increasing in autumn and winter. Winter is the richest season in the natural environment, while it decreases considerably in the pine grove.

The minimal Equitability of the media are due to massive flocks of *Xenylla maritima* appearing in spring in the bushes and in winter in the pine forest.

Autumn and winter are the most favourable seasons for the microarthropod fauna of the bush soil. This biotope is more complex (it is richer) and more stable (it has a higher Equitability). Critical seasons are spring and summer for both biotopes. In these moments the microarthropod populations of the pine soils are more stable, possibly because of the protection that the forest offers against adverse climatic conditions.

In the bush soil forty-eigth species of nematoda were found, thirty of them being exclusive of the bush and disappearing from the pine grove soils. This last environment shows a poorer fauna, with only ten exclusive species out of a total of twenty-eight. The Richness is higher in bush soils than in pine soils, presenting two maximums in summer and autumn. The Equitability is smaller in the bush soils, because of a massive population of *Aphelenchoides parietinus* in summer and the addition of *Paraphelenchus pseudoparietinus* in autumn. The pine grove diminishes the complexity of the nematoda biocenose (the Richness is smaller), but, however, it is a more stable biotope than the bush (greater Equitability).

A correspondences analysis was performed with the sixty-eigth species of Collembola, Oribatei and Nematoda that occurred at one percent or higher abundance. The first axis relates to the 34.49% of the total variance and the second axis does to the 19.24%. In fig. 2 we may observe that the first axis groups in one part all the samples of the pine grove soils, separating them from the bush soil samples placed in the opposite half. This fact points to a great substitution of species between both media. It is interesting to point out that the dots associated with the nematoda lay preferably around the coordinates corresponding to the bush samples. The exclusive species from this biotope are: *P. acuminatus, P. opistocirculus, C. troglophilus, H. teres, D. gr. lutonensis, N. alli, D. durus* and *E. monohystera;* other species common to both biotopes but favoured in the bush environment are: *T. auriculatus, C. persegnis, E. mucronatus, P. pseudoparietinus, A. parietinus, L. penardi, N. cylindricus, E. miser* and *D.* cf. *monticolus.* The pine grove holds no exclusive species, nor has it any preferential one. The Collembola show a similar behaviour, the bush soils presenting the exclusive species *C. engadinensis, H. vernalis, P. parvulus, M. krausbaueri, O. minutus, P. nemorata, C. thermophilus* and *P. minuta.* Whereas there is no exclusive species in soils from the pine grove, *I. (P.) notabilis* is well represented. The acari Oribatei populations show quite a different behaviour. Although there are relatively many exclusive species in the bush (*A. coleoptrata, C. horrida, H. vin-*

dobonensis, L. costula, L. sellnicki, P. ocris and *T. tectorum*), some species are exclusive of the pine soils (*L. leonthonycha, S. subtrigona* and *X. tegeocranus*). Also, there is a group of well represented but not exclusive species in the pine soils: *O. confinis, O. serrata, O. nova, Q. quadricarinata, S. sarekensis* and *T. alatus.*

FIG. 2.

Correspondences analysis made with 68 species (Nematoda 27, Oribatei 26, Collembola 15) from soils of spring (S), summer (S'), autumn (A) and winter (W) of the mediterranean bushy land and a reafforested area with pine *(Pinus halepensis).*

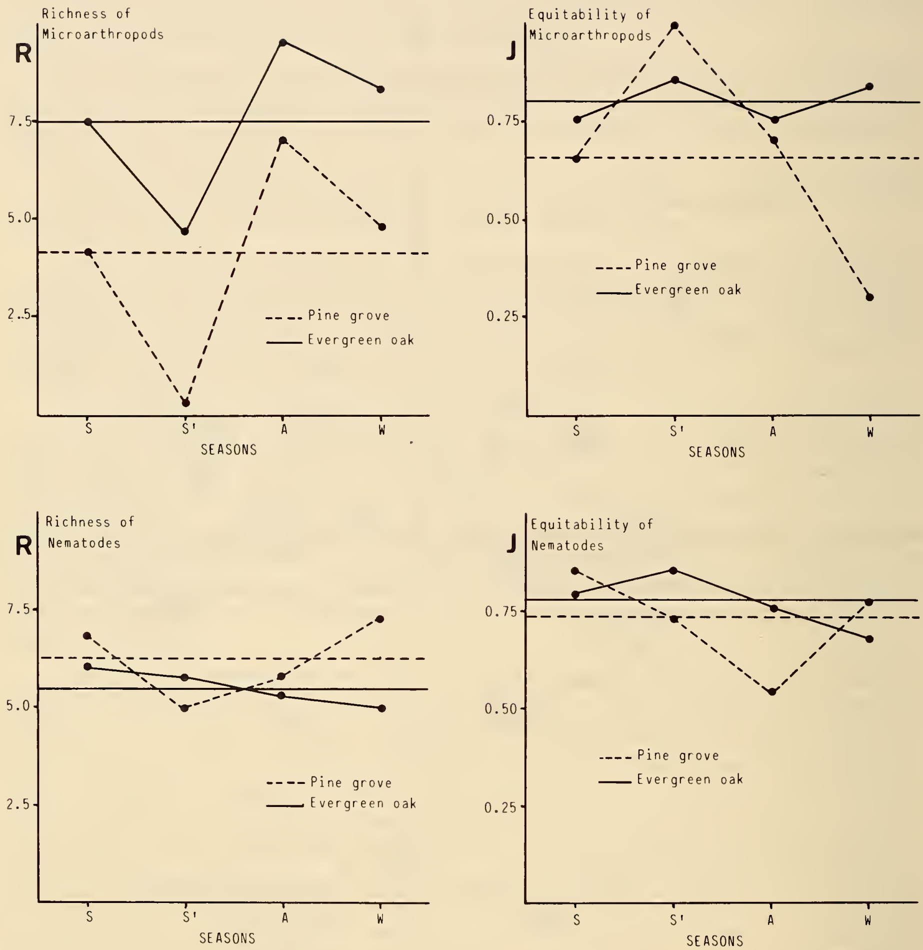

FIG. 3.

Seasonal variation of Richness (R) and Equitability (J) in Sansoain S: Spring; S': Summer; A: Autumn; W: Winter. Horizontal lines: Average of each one.

Sansoain

In the soils of evergreen oak grove a total of 183 species (eighty of Oribatei, thirty-eight of Collembola and sixty-five of Nematoda) have been found. Out of them, fifty-two Oribatei sixteen Collembola and twenty-seven Nematoda are exclusive of this environment, having disappeared in the pine forest. In the soils from pine grove a total of 149 species (forty-five Oribatei, thirty-two Collembola and seventy-two Nematoda) have been found. Out of them, seventeen Oribatei, ten Collembola and seventy-two Nematoda are exclusive of these soils.

The microarthropods Richness (fig. 3) is lesser in the soils from pine grove than in the evergreen oak forest throughout the year. Both biotopes show a minimum in summer and two maximums, one in autumn and other in winter. The Equitability is smaller in soils from pine grove, and interesting to notice the minimum of Equitability in winter by *T. tectorum* and *H. vernalis* dominance. The faunal populations in evergreen oak soils are more complex and more stable. The Nematoda populations behaviour are quite different, the soils from pine forest are richer than evergreen oak soils in spring and winter, but the latter is more stable (Equitability highest and constant throughout the year). The minimum of Equitability in the pine soils is in autumn due to the great amount of *P. rhizophilus.* The soils from pine grove show faunal populations more complex but less stable than those of the natural environments.

From 245 species found in Sansoain in both media 78 have been selected (Abundance $>1\%$) to make a correspondences analysis (fig. 4). The first axis support the 33.57% of the variance and the second axis the 19.15%. First axis groups the pine grove soils in the positive values and in the opposite place the evergreen oak soils. The exclusive species of these environments are plotted around the seasonal samples and are enlarged following the second axis, they are indicating the seasonal substitution of the species.

Soils from evergreen oak forest by following species are characterized: *E. simplex, C. assimilis, C. loricatus, P. rigidus, P. myceliophthorus, D. brasicae, M. bastiani, X. tullbergi, P. armata, C. debilis, F. gr. fimetaria, P. xavieri, D. minuta, E. cordiformis, P. perlongus, R. elliptica, R. translamellata, S. anomalus, C. jugata, E. granulatus* and *O. obsoleta;* instead of the soils from pine grove only have as exclusive species: *Aporcelaimellus* sp., *C. papillatus, E. pseudobulbosa, R. clavata* and *T. tectorum.*

DISCUSSION

The potential vegetation substitution (mediterranean bush and evergreen oak grove) by a reafforestation with coniferous trees (*Pinus halepensis* and *Pinus nigra*) produce a rupture on the dynamics and structure of the soil fauna populations. The soil fauna become poorer specifically and numerically. We can see too that few species appear as exclusives from pine forest soils, and only some species, which have high ecological valence, are able to adapt to the new conditions.

We point out specially that in Bardenas, reafforestation with *Pinus halepensis* (closed environment) from an open land (mediterranean bush) do not produce an increasing in species and specimens number of the edaphic fauna; these effect could be expected because of the better protection from evaporation and insolation that the pine forest offers. Perhaps the organic matter excess contributed by the pine, as well as the very short period with enough humidity, makes its degradation very difficult.

FIG. 4.

Correspondences analysis made with 78 species (Nematoda 31, Oribatei 29, Collembola 18) from soils of spring (S), summer (S'), autumn (A) and winter (W) of the evergreen oak grove *(Quercus rotundifolia)* and a reafforested area with pine *(Pinus nigra)*.

These considerations for application of T index of LOOMAN & CAMPBELL are confirmed. Calculations have been made with all species of Nematoda, Oribatei and Collembola found in the samples (figs 5 and 6). In these clusters we can see that the significant similarity among seasonal soil samples from each plant formation is established. There is a complete gap between natural and reafforested media, which shows the rupture of ecological equilibrium and a high species substitution.

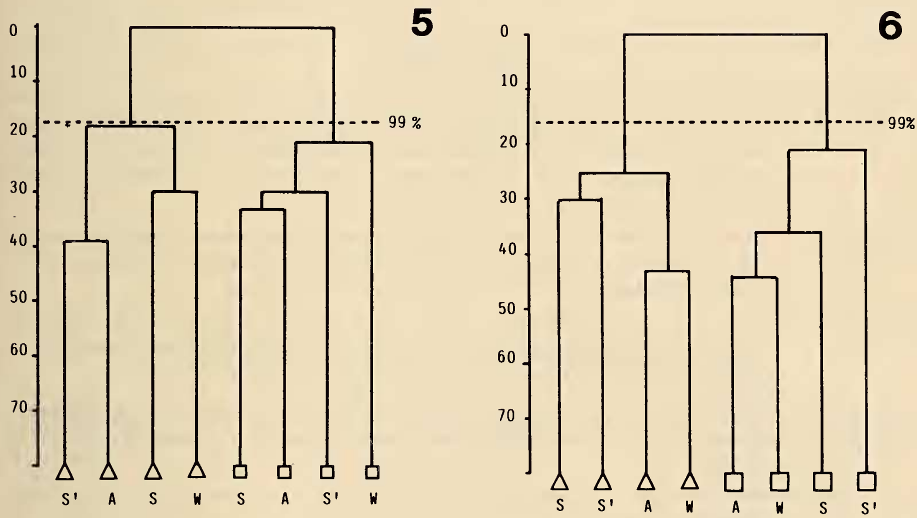

FIG. 5.

Cluster of the eight "Biotopes-Season" from Bardenas, based on association index T of Looman-Campbell. Broken line: 99% confidence level. Triangles: Soils from mediterranean bushy land; Squares: Soils from reafforested area with *Pinus halepensis*. S, S', A, W: as figures 1 and 2.

FIG. 6.

Cluster of the eight "Biotopes-Season" from Sansoain, based on association index T of LOOMAN & CAMPBELL. Broken line: 99% confidence level. Triangles: Soils from evergreen oak grove; Squares: Soils from reafforested area with *Pinus nigra*. S, S', A, W: as figures 1 and 2.

SUMMARY

Two areas have been studied in order to determine the effects of reafforestation by conifers: (1) Middle Navarra: an evergreen oak forest *(Quercus rotundifolia)* and a Corsican pine grove *(Pinus nigra laricio)*. (2) South Navarra: a thicket biotope of the semiarid mediterranean bushy land and an Aleppo pine forest *(Pinus halepensis)*.

Sampling was performed four times in the years 1982-83. The microarthropods were extracted by TULLGREN's funnel. Nematoda were extracted by centrifugal flotation method (NOMBELA & BELLO 1983 modified). The study includes the specific analysis of the Nematoda, Oribatei and Collembola.

The analysis of Equitability, Richness and Similarity, as well as comparisons among biotopes by means of correspondences analysis, show that reafforestation causes a clear rupture of the soil fauna ecological equilibrium, meaning thus an impoverishment of it. Effects are more dramatic in the biotope which stands the most extreme environmental conditions (South of Navarra).

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TABLE I.

List of species and abbreviations used in correspondences analysis.

BARDENAS: Species from soils of mediterranean bush and pine grove

NEMATODA		ACARI ORIBATEI		COLLEMBOLA	
Al	*Acrobeles singulus*	Ac	*Achipteria coleoptrata*	Ce	*Ceratophysella angadinensis*
Ab	*Acrobeloides buetschlii*	As	*Aleurodamaeus setosus*	Ct	*Cryptopygus thermophilus*
An	*Acrobeloides nanus*	Ar	*Allodamaeus reticulatus*	Em	*Entomobrya multifasciata*
Ap	*Aphelenchoides parietinus*	Ch	*Camisia horrida*	Fs	*Folsomia sexoculata*
Ao	*Aporcelaimellus obscurus*	Cl	*Cosmochthonius lanatus*	Fa	*Folsomides angularis*
Ce	*Cephalobus persegnis*	Dt	*Damaeus torquisetosus*	Hm	*Heteromurus major*
Ct	*Cephalobus troglophilus*	Hv	*Haplozetes vindobonensis*	Hv	*Hypogastrura vernalis*
Cv	*Cervidellus vexilliger*	Hi	*Hemileius initialis*	In	*Isotoma (Parisotoma) notabilis*
Dd	*Deladenus durus*	Lc	*Licneremaeus costula*	Mk	*Mesaphorura krausbaueri*
Dl	*Ditylenchus gr. lutonensis*	Ll	*Liebstadia leonthonycha*	Om	*Onychiurus minutus*
Dm	*Dorylaimellus* cf. *monticolus*	Ls	*Liochthonius sellnicki*	Pm	*Proisotoma minuta*
Em	*Ecumenicus monohystera*	Oc	*Oppia confinis*	Pn	*Protaphorura nemorata*
Eu	*Eucephalobus mucronatus*	Os	*Oppia serrata*	Pp	*Pseudachorutes parvulus*
Ei	*Eudorylaimus miser*	On	*Oppiella nova*	Sp	*Sphaeridia pumilis*
Hs	*Heterocephalobus* spp.	Oe	*Oribatula exudans*	Xm	*Xenylla maritima*
Ht	*Heterocephalobus teres*	Ot	*Oribatula tibialis*		
Lp	*Laimaphelenchus penardi*	Pa	*Pilogalumna allifera*		
Na	*Nothotylenchus allii*	Po	*Psudoppia ocris*		
Ns	*Nothotylenchus* spp.	Qq	*Quadrioppia quadricarinata*		
Nc	*Nototylenchus cylindricus*	Ss	*Suctobelbella sarekensis*		
Pp	*Paraphelenchus pseudoparietinus*	Su	*Suctobelbella subcornigera*		
Pa	*Plectus acuminatus*	Sb	*Suctobelbella subtrigona*		
Pc	*Plectus cirratus*	Ta	*Tectocepheus alatus*		
Po	*Plectus opisthocirculus*	Tt	*Thrypochthonius tectorum*		
Ps	*Plectus* sp.	Xt	*Xenillus tegeocranus*		
Ts	*Tylenchus* spp.	Xa	*Xenillus* cf. *anasillus*		
Ta	*Tylocephalus auriculatus*				

SANSDAIN: Species from soils of evergreen oak and pine grove

NEMATODA

Ag *Acrobeles singulus*
Al *Aphelenchoides* cf. *silvester*
Ap *Aphelenchoides parietinus*
Ao *Aporcelaimellus obscurus*
As *Aporcelaimellus* sp.
Bt *Bunonema tuerkorum*
Cr *Ceratoplectus armatus*
Ca *Ceratoplectus assimilis*
Cv *Cervidellus vexilliger*
Cl *Chiloplectus loricatus*
Cp *Clarkus papillatus*
Db *Ditylenchus brasicae*
Es *Eudorylaimus* spp.
Ep *Eumonhystera pseudobulbosa*
Ex *Eumonhystera simplex*
He *Heterocephalobus elongatus*
Mb *Mesodorylaimus bastiani*
Ms *Mesorhabditis* cf. *spiculigera*
Ns *Nothotylenchus* spp.
Pr *Panagrolaimus rigidus*
Pm *Paraphelenchus myceliophthorus*
Pa *Plectus acuminatus*
Pc *Plectus cirratus*
Po *Plectus opisthocirculus*
Pv *Plectus parvus*
Pz *Plectus rhizophilus*
Ps *Plectus* sp.
Pu *Prionchulus muscorum*
Pt *Protorhabditis tristis*
Ts *Tylenchus* spp.
Ta *Tylocephalus auriculatus*

ACARI ORIBATEI

Cs *Camisia spinifer*
Cj *Cerachipteria jugata*
Cb *Chamobates borealis*
Cc *Chamobates schutzi*
Ec *Eremaeus cordiformis*
Er *Eremaeus granulatus*
Hi *Hemileius initialis*
Hd *Hermanniella dolosa*
Hs *Hypodamaeus* sp.
Ob *Oppia bicarinata*
Ol *Oppia concolor*
Om *Oppia minutisima*
Oo *Oppia obsoleta*
On *Oppiella nova*
Pp *Punctoribates perlongus*
Qq *Quadrioppia quadricarinata*
Re *Ramusella (I.) elliptica*
Rt *Ramusella (I.) translamellata*
Ra *Ramusella (R.) assimilis*
Rc *Rhysotritia clavata*
Rd *Rhysotritia duplicata*
Sa *Steganacarus anomalus*
St *Suctobelba trigona*
Ss *Suctobelbella sarekensis*
Su *Suctobelbella subcornigera*
Sb *Suctobelbella subtrigona*
Ta *Tectocepheus alatus*
Tt *Thrypochthonius tectorum*
Xt *Xenillus tegeocranus*

COLLEMBOLA

Cd *Cryptopygus debilis*
Dm *Dicyrtomina minuta*
En *Entomobrya nivalis*
Ff *Folsomia* gr. *fimetaria*
Fs *Folsomia sexoculata*
Fu *Friesea subterranea*
Hm *Heteromurus major*
Hv *Hypogastrura vernalis*
In *Isotoma (Parisotoma) notabilis*
Im *Isotomiella minor*
Ip *Isotomurus palustris palustris*
Lc *Lepidocyrtus cyaneus*
Mk *Mesaphorura krausbaueri*
Pa *Protaphorura armata*
Px *Pseudosinella xabieri*
Sa *Sminthurinus aureus*
Xn *Xenylla maritima*
Xt *Xenylla tullbergi*